Chapter 25
Fortification of Flour and Outcomes: Oman's Perspective—Contextual Considerations and Outcome

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Key Points

- Oman is a stable country transiting from being a developing to developed country; education, income, and health services are on the rise.
- Oman was a leader in making flour fortification a national legislation, and the coverage rate was more than 80 % consistently over the years.
- Political well: a well set up industry and open communication channels facilitated the initiation and sustainability of the fortification program.
- Process and coverage was established because of the small number of mills and adequate resources.
- The most important impact was on NTDs which declined significantly to 20 % of its original levels and saved about 1,350 births from 1996 to 2010.
- Anemia rates went down among women of childbearing age and adolescents, but had increased among preschool children and remained constant among men. It continues to be a public health problem of concern.
- Impact of iron and folate fortification is dependent on the bioavailability of each nutrient, and other confounding factors, such as the presence of comorbidities and genetic haemoglobinopathies.
- Anemia control is a complex issue that requires a comprehensive and holistic approach in policy and management.

Keywords Fortification • Oman • Iron • Folate • Flour fortification • Anemia • NTDs • Spina bifida • School children • Women • Men

Abbreviations

UAE	United Arab Emirates
KSA	Kingdom of Saudi Arabia
Km	Kilometers

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V.R. Preedy et al. (eds.), *Handbook of Food Fortification and Health: From Concepts to Public Health Applications Volume 2*, Nutrition and Health, DOI 10.1007/978-1-4614-7110-3_25,

Sq	Square
GDP	Gross Domestic Product
US	United States
$	Dollars
UNICEF	United Nations Children Fund
PEM	Protein energy malnutrition
Hb	Hemoglobin
g/dL	Grams per deciliter
mg	Milligram
μg	Microgram
IU	International units
μg/dL	Microgram per deciliter
WHO	World Health Organization
EMRO	Eastern Mediterranean Regional office of the World Health Organization
CDC	Centers for Disease Control
USA	United States of America
ppm	Parts per million
Mt/day	Metric tons per day
OR	Omani Rials
RNI	Recommended nutrients intake
UN	United Nations
EAR	Estimated average requirements
mg/d	Milligram per day
NTDs	Neural tube defects
QALYs	Quality adjusted life years
MoH	Ministry of Health

Introduction

Flour fortification was initiated in Oman in 1996, making this small Middle Eastern nation the first to mandate folic acid fortification globally. In that year, as the United States of America was fortifying on a subnational scale, Oman health authorities took the courageous first step to issue a national legislation that requires all white flour in the country to be fortified with iron and folic acid. Currently, 63 countries require iron fortification, and 57 of them require folic acid fortification of flour.

The impact of folate fortification is well documented in Oman and the world. However, the question that presents itself: Was the decision to fortify flour with iron and folate in 1996 a lucky draw or an educated guess by the Omani health authorities? Does the current outcome meet the expectations at that time? These and contextual factors will be discussed in order to gain a more in depth understanding of Oman's perspective on flour fortification.

Overview of Oman: Geography and Economy

The Sultanate of Oman is an Arab state in southwest Asia on the southeast coast of the Arabian Peninsula. It is bordered by the United Arab Emirates (UAE) to the northwest, Kingdom of Saudi Arabia to the west and Yemen to the southwest. The coast is formed by the Arabian Sea on the southeast and the Oman Sea on the northeast. Madha and Musandam enclaves are surrounded by the UAE on their land borders, with the Strait of Hormuz and Gulf of Oman forming Musandam's coastal boundaries [1].

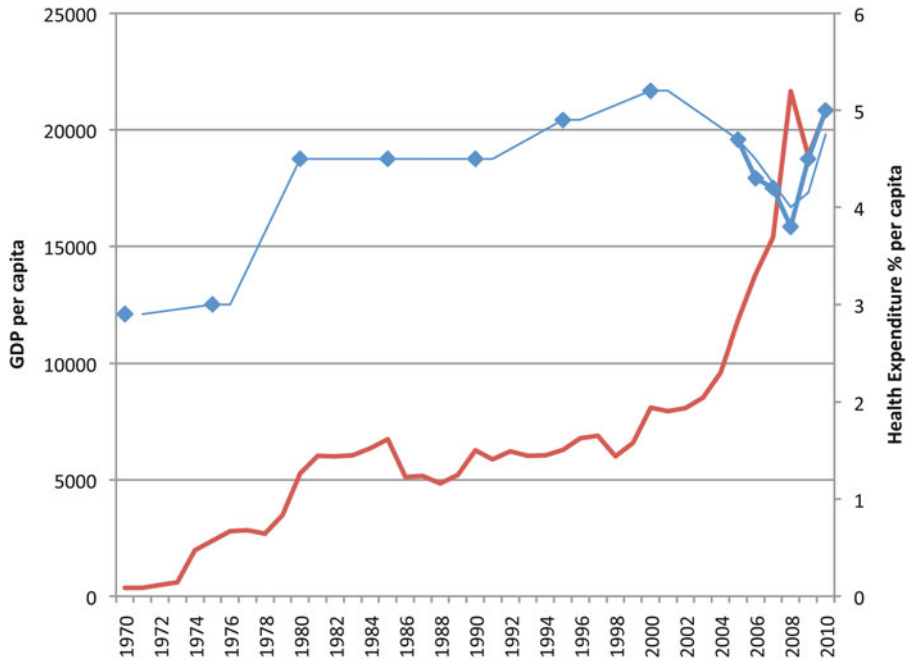

Fig. 25.1 Gross domestic product per capita and percentage expenditure on Health for Oman from 1970 to 2010 (Adapted from World Bank; Ministry of National Economy, Oman [43, 51])

The total area of Oman is estimated to be 309,500 km^2 and its coastline extends for 3,165 km [2, 3]. It has a variable landscape of desert, beach, and mountain terrains and has 9,000 ha of irrigated land and 39,000 ha of permanent crops [4].

Despite its dependence on oil, Oman's production is comparatively low compared to countries like KSA and Libya. Almost 67 % of the national revenue comes from oil, and an additional 11–12 % from gas [5].

GDP per capita reached a high of US$21,065.6 in 2010, showing a steady increase from US$8,283.9 in 2000 and US$12,334.4 in 2005 [6]. Health expenditure however did not increase significantly as it was only 2.1 % of the GDP in 2008, which may have been caused by high cost of the developmental projects in order diversify sources of income [7]. In the year 2000, a controversial report by the World Health Organization ranked Oman first on performance on level of health [8, 42, 43, 47, 51] (Fig. 25.1).

Demographics, Health and Nutrition

In 2010, Oman population size was estimated to be 2,750,000 of which 29.5 % were expatriates; males were 102.5 and 138 per 100 females for the Omani and total populations respectively. About 13.5 % of the population were under 5 years and another 35.3 % were under 15 years whereas only 3.6 % were 60 years and over. Women in reproductive age comprised about 27.2 % of the population. Crude birth rate in 2010 was estimated to be 31, crude death at 3.3 per 1,000 population and the total fertility rate was 3.7 and life expectancy was 76.1 years [2, 9].

The State of the children 2011 of UNICEF reported that 88 % of the population had access to improved drinking water sources, 97 % had improved sanitation facilities, both improving from 80 % in 1990. Immunization coverage went from less than 80 % in 1990 whereas under 5 mortality rate was 11.3/1,000 live births in 2010 from 35 in 1990 [10, 11].

The first documented investigation of protein energy malnutrition (PEM) and micronutrients deficiencies was in 1980 when a United Nations mission to the Gulf Region reported that 62.9 % of preschool children were underweight and 24.1 % were stunted [12]. In 1992, the rates had decreased to 32–46 % for stunting and 25–37 % for underweight [13]. These continued to decline as stunting was reported to be 10.6 % in 1999 and 9.8 % in 2009, whereas underweight was 17.9 % in 1999 and 8.6 % in 2010 [14, 15].

A national strategy to combat child malnutrition was introduced in 2004 and included early screening and management, social marketing campaign and a number of other multi-sector activities. Malnutrition was reduced probably because of the economic, social, educational, and health progress in addition to the interventions that took place during that period [12, 16].

Status of Micronutrients Malnutrition in 1996

Micronutrients Malnutrition was one of the most important issues tackled in health since 1980s when population surveys showed high prevalence estimates of anemia, vitamin A, and iodine deficiency disorders.

Anemia: A national study in 1986 reported that 54 % of pregnant women in Oman had hemoglobin (Hb) values less than 11 g/dL [17]. In the same year, an iron supplementation program for all pregnant women was implemented, which required all pregnant women to receive 200 mg of ferrous sulfate and 5 mg of folic acid daily [18]; however, 48.5 % of Omani pregnant women were still anemic in 1993 [19, 45].

Vitamin A: In 1981, the first study of vitamin A status in Oman found that 1.5 % of preschool children had Bitot's spots [20]. In 1994, a national study of vitamin A status in children 7 and 18 months, 3 and 6 years of age found that 18.7 % of the study population had serum retinol levels below 20 μg/L and 2.1 % had serum retinol levels below 10 μg/L indicating severe deficiency [21]. Following that (in 1995), universal supplementation was initiated for postpartum women at 200,000 IU, as well as 100,000, 200,000 IU for children at 9 and 15 months consecutively. In 1999 the prevalence of serum retinol levels less than 20 μg/L among children was reduced to 5.2 % and no children had serum retinol levels below 10 μg/L [22].

Iodine deficiency disorders: Universal salt iodization was legislated in Oman in 1996 after a household survey revealed that 22 % of households used iodized salt, 50.2 % of schoolchildren had urinary iodine levels below 100 μg/dL, and 1.2 % had goiter [23].

Initiation of the Flour Fortification Program in Oman

As flour fortification was being initiated in 1996, vitamin A and iodine deficiencies were on the decline among infants and children in Oman; at the same time child malnutrition and anemia among all age groups were known to be unacceptably high. Extrapolating from international data, iron deficiency was assumed to be the main cause of anemia in the region and thereby fortification was considered the intervention of choice [24].

A multi-organization consultation was held in Muscat, Oman and it concluded that fortification would potentially contribute to the reduction of anemia among women and children in Oman [25]. The consultation was a coordinated effort between the WHO offices in Oman and EMRO (personal communication, Dr. Anna Verster), and WHO, UNICEF, Micronutrients Initiative and Program on Micronutrients Malnutrition (CDC/USA). It was decided that "fortification of flour in most countries in the region will be simple and cheap and will be a major strategy to prevent anemia", and "ferrous

sulphate is the compound of choice, folic acid can be added at little additional cost". Oman consented to 30 iron and 1.5 ppm folic acid fortification level.

Flour is a stable commodity and does not change in color, taste, or consistency upon fortification which makes it an attractive option as a vehicle. Criteria for choosing a fortificant are explained in Chap. 7 with more detail. Population coverage was expected to be high as almost 80 % of the flour was supplied by one mill [26].

Oman Flour Mills (OFM) was the only mill in the country and supplied more than 80 % of the flour and bread demand with 800 Mt/day capacity. Main types of flour produced were the atta flour with high extraction rate of 87 % and accounted for 60 % of the production in 1996, and low extraction rate flour that accounted to 40 % of the production. Fiber content of high extraction flour inhibits iron absorption therefore it was decided to fortify the white flour only [27, 52].

Political Support

Early 1997, a legislation to mandate fortification of flour with 30 ppm iron and 1.5 ppm folic acid was issued by Ministry of Commerce and Industry and Oman Flour Mills complied with the legislation [27, 28]. Swift fortification of flour in Oman had elements of political support, dedicated management, and a convenient technical and logistic set up.

The Minister of Health at the time. was also the Chairman of Board for Oman Flour Mills. a rare incident that was detrimental in expediting the process. Concerned about the public health implications of anemia, he consulted with the World Health Organization in Muscat and EMRO and requested expert advice on the feasibility of flour fortification in Oman (personal communication).

Oman Flour Mill capacity was recognized by experts and it was stated that fortification could proceed without delay. There were no requirements for additional equipment, supplies, or manpower besides procurement of the fortificant. Fortification and the quality schemes it required could be incorporated easily because of the modern technology used in the mills. Shortly after this evaluation, a consultation gathered experts from Eastern Mediterranean Region (EMRO countries) and the rest of the world in the capital of Oman. At the time, the United States was in the process of mandating fortification which persuaded the crowd who knew that many commodities were already fortified for more than 50 years in that country.

The workshop consensus was the basis for the legislation issued by Ministry of Commerce and Industry shortly after. As for the operations management team, the expert visit and discussions of technical and finance queries paved the way to prompt implementation. In addition, low cost of fortification and high market share made it less difficult for them to take part.

In 2004, an evaluation of the flour fortification and micronutrients program took place. including qualitative and quantitative studies to assess anemia and flour fortification knowledge, attitude and practices among Omani families, and to determine the coverage and impact of fortified flour on anemia and iron status of women and children [29, 30].

Knowledge, Attitudes of Anemia and Flour Fortification

A number of studies demonstrated that knowledge of anemia and fortification was very low among Omanis. In 1993, about 51 % of pregnant women had some knowledge about anemia. but only 2.4 % related it to iron deficiency [31]. In 2003, a qualitative study indicated that there was a general lack of knowledge about micronutrients deficiencies and fortification, although many people were aware of additives and their hazards. There was no clear distinction between nutritional and genetic anemia in the population studied, moreover fortification was discussed with suspicion on the basis of possible

side effects. carcinogenesis and allergic reactions. Most respondents were not aware that flour is fortified. including a baker and health staff, although many were aware that salt was iodized possibly because there was a marketing campaign for the latter. When asked, most participants chose non-fortified flour [29].

A quantitative study a year later reported that 4.5 % of women and 7.9 % of the men knew that bread is fortified, and 4.5 % of the women and 4.7 % of the men knew that flour is fortified. Only 14.9 % of the women and 33.2 % of the men reported choosing fortified products in the stores. Fortification ranked higher on men's priority list when purchasing food as 10.8 % of them took it into considerations compared to only 4.2 % of women. Younger women chose fortified products more than older women ($p<0.05$) [30].

Flour was commonly purchased as almost 90 % of the households reported to have flour, and 79 % reported to consume Chappati and Omani bread which are home made. The coverage of flour fortification was 81 %.

In the same study, households with higher per capita income were more likely to have fortified flour. Only 51.6 % of lower income households had fortified flour compared to 84.2 % for the highest income quartiles. The percentage of fortified flour in low income households (per capita <R.O. 30[1]) was 64.9 %, compared to 83.4 %, in high income households (p-value = 0.005). Flour bought from local mills was the least fortified (44.4 %), though only 2.7 % of the houses bought from those mills.

Knowledge about flour fortification is low among this population; however, consumption of fortified flour seems to be high. None of the studies investigated folic acid fortification.

Bioavailability, Consumption and Nutrient Adequacy

Iron: Animal foods and ascorbates are important enhancers of non-heme iron absorption, while phytates, polyphenols, tannins, and fiber are considered as inhibitors. Recommended nutrition intake of cereal-based diet and low ascorbate content is set at <5 % (very low bioavailability) or 5–10 % or low bioavailability.

An intermediate diet with a bioavailability of 11–18 % is based on plant foods with some animal protein and ascorbic acid. High bioavailability diet (19 % absorption), is predominantly animal protein diet and with fruits rich in ascorbic acid. Omani diet was considered of intermediate bioavailability and was estimated to be 12 % [32, 33].

Consumption of flour was estimated to be 286 Mt per capita daily in 1995 [34]. Fig. 25.2 shows the percentage contribution of iron from fortification to the total iron intake among men and women. Iron intake of diet alone was lower than the estimated average requirements for children, women, and adolescents, whereas fortification at 30 ppm provided additional 8.0 mg per day for adolescents (50 %), 7.5 mg for women (46.6 %), and 8.6 mg for men (42 %). This addition exceeded the requirements for adolescents and men but achieved only 80 % of the requirements for women.[2]

Folate: Before fortification only 35 % of the folate requirements were satisfied by the diet, which went up to 93 % after fortification of folic acid. At least 59 % of the folate is supplied by wheat flour [33] (Table 25.1).

[1] Exchange rate: US$1 = 0.388 Omani Rial (OR); 30 OR = US$77.

[2] Calculated from the national dietary intake survey.

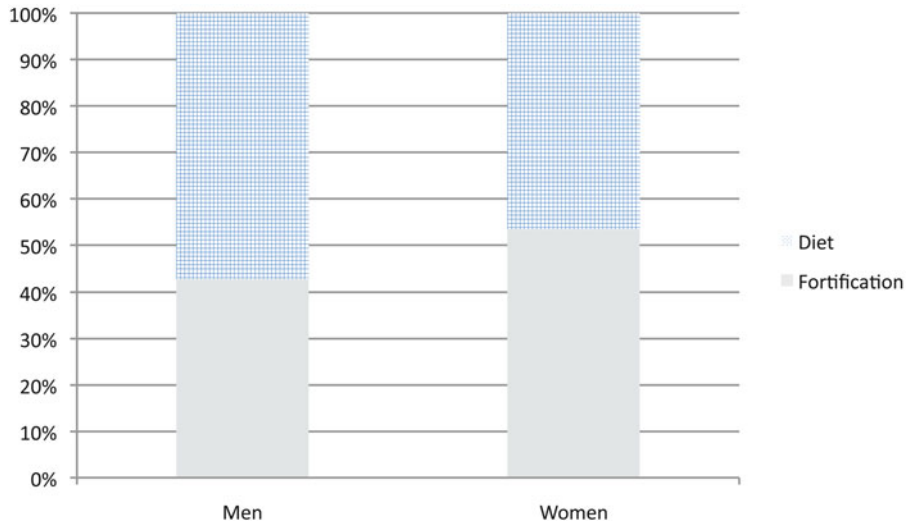

Fig. 25.2 Contribution of fortification to iron intake among Omani men and women (2004) (Adapted from National Nutrition Survey, Oman)

Table 25.1 Iron and folate requirements for Omani population, 2007 (MoH, Oman) [33]

Population category	Age group (years)	Energy (kcal)	Iron (mg)	Folate (μg)
Young children	1–3	1,000	5.5	150–200
Children	4–8	1,400	7.7	210–280
Adolescent males	9–13	2,000	11.0	300–400
	14–18	3,000	16.5	450–600
Adolescent females	9–13	1,900	10.5	285–380
	14–18	2,400	13.2	360–480
Adults males	19–30	2,100	11.6	315–420
	31–50	2,400	13.2	360–480
	51–70	2,200	12.1	330–440
	>70	1,800	9.9	270–360
Adults females	19–30	2,000	11	300–400
	31–50	2,000	11	300–400
	51–70	1,800	9.9	270–360
	>70	1,600	8.8	240–320
Pregnant women	All	2,100–2,700	11–15	315–540
Lactating women	All	2,400–2,900	13–16	360–580

Impact of Flour Fortification

As fortification of cereals with iron was practiced as early as 1952 in USA and Canada, it was considered an acceptable and safe strategy but the impact of fortification on anemia was more pronounced in developing countries where the reduction was 30–70 % compared to <20 % in developed countries. Moreover some subgroups were found to consume less fortified products or at higher risk of anemia (refer to Chap. 7). The human development index 2011 placed Oman higher than other eastern

Mediterranean countries based on this nation's health, education, and income. Because of that, and the ever rapid changing pattern of nutrition and morbidity, Oman cannot be compared to developed or developing countries nor can anemia improvement be predicted [35].

Anemia Among Preschool Children

Diet of children below the age of 5 years goes through several stages starting from breastfeeding up to the age of 6 months; complementary feeding to the age of 12 months and transition to family diet [36]. Iron status is determined by dietary practices as well as the health and nutritional status of the child. These are beyond our scope, although estimated iron intake and anemia status in this population are going to be investigated.

Flour intake of children below the age of 2 years is small or minimal, and may be confounded by the extent of breastfeeding therefore flour fortification is not expected to have a significant impact on anemia in this age group.

The national nutrition survey in 2004 indicated that iron intake for infants and young children was above the recommended intake, whereas the trend indicates an increase in anemia from 1995 to 2009 as shown in Fig. 25.3. At the age of 0–2 years however the rates were comparable, whereas a gradient increase is observed at the 3–5 age group, resulting in an overall increase of 20 % in 14 years [14, 37, 48, 50].

Anemia Among Adolescents

Mean intake of iron was 14.6 mg compared to the 18.6 RNI, indicating that dietary iron among Omani adolescents does not satisfy biological requirements. In 1980, a UN mission indicated that anemia rates among adolescents was 58.5 %, and in 1996 a school children survey found low Hb level of

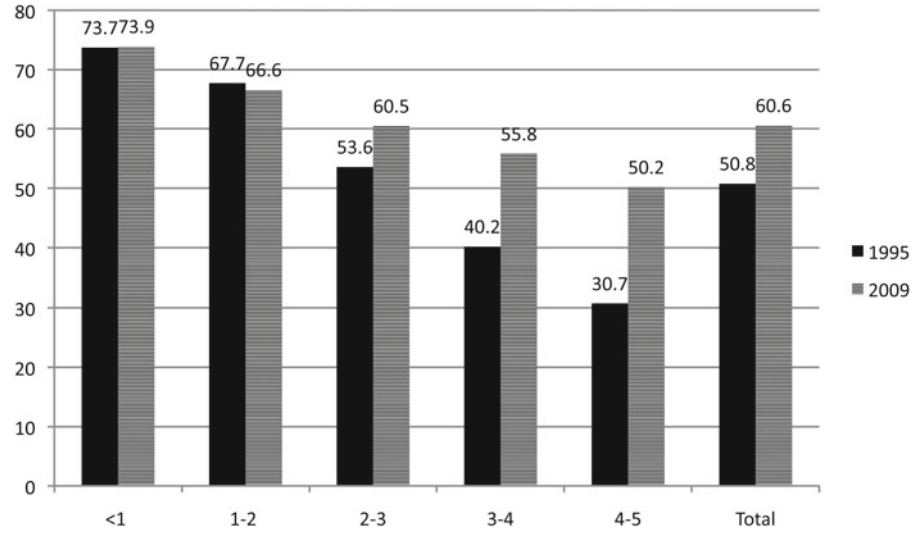

Fig. 25.3 Anemia rate among infants and young Omani children in 1995 and 2009 (Adapted from ElSayed et al. [15]; Al-Riyami et al. [19])

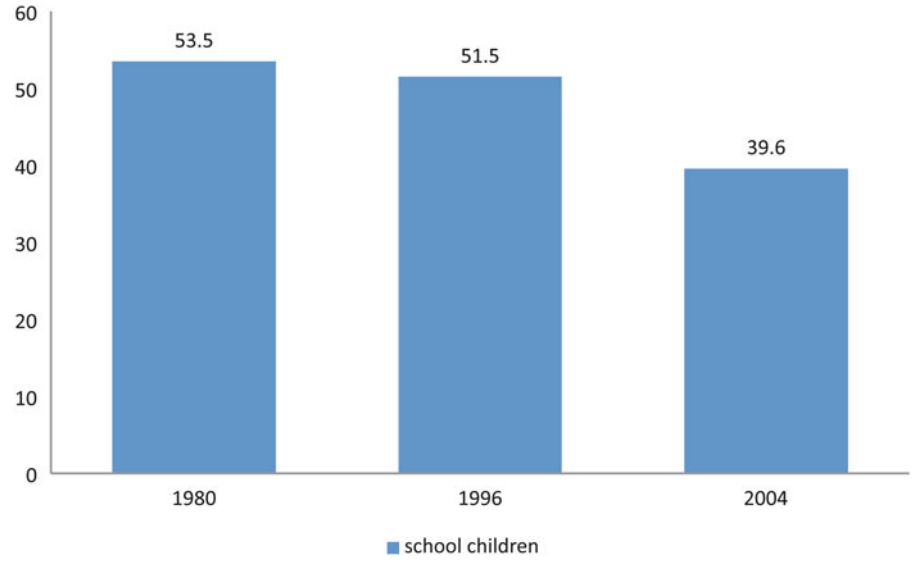

Fig. 25.4 Rate of anemia among Omani school children (Amine [12]; Alasfoor [36]; MoH, Oman, 2009)

51.5 % (95 % CI = 47.7–55.3), and in 2004 dropped by 23–39.6 % (95 % CI = 28.5–51.8) as shown in Fig. 25.4 [12, 38], The rate of decline in 1980–1996 before fortification was 0.31 per year, whereas it was 1.48 after fortification.

Anemia Among Women of Childbearing Age

Women in childbearing age had low iron intake similar to adolescents, as the mean intake was 16.1 ± 10.3, whereas the RNI was 24.5 mg/day and the EAR = 20.4 mg/day. The contribution of iron in fortified flour however was significant as indicated earlier, as more than 50 % of iron was provided through fortification (Fig. 25.2).

A surveillance system was established to monitor the hemoglobin levels as they enter into pregnancy in the early 1990s. As shown in Fig. 25.5, anemia levels witnessed a consistent decline of 0.8 % annually over the last 16 years, which indicates a positive response to fortification. It can be argued however that developmental progress, education, and wealth could have significantly impacted the nutritional status of women.

Neural Tube Defects

The most widely used outcome measure of folic acid fortification is reduction of neural tube defects, because of the severity of the problem and the outstanding reduction shown worldwide [39]. Similarly in Oman a reduction of spina bifida was observed consistently from 1996 to 2010, contrary to earlier dates where other NTDs were constant. Figure 25.6 shows the incidence of spina bifida as well as other congenital disorders reported from 1991 to 2010. Spina bifida went down by 86 %, from 3.48 to 0.68 per 1,000 births [40].

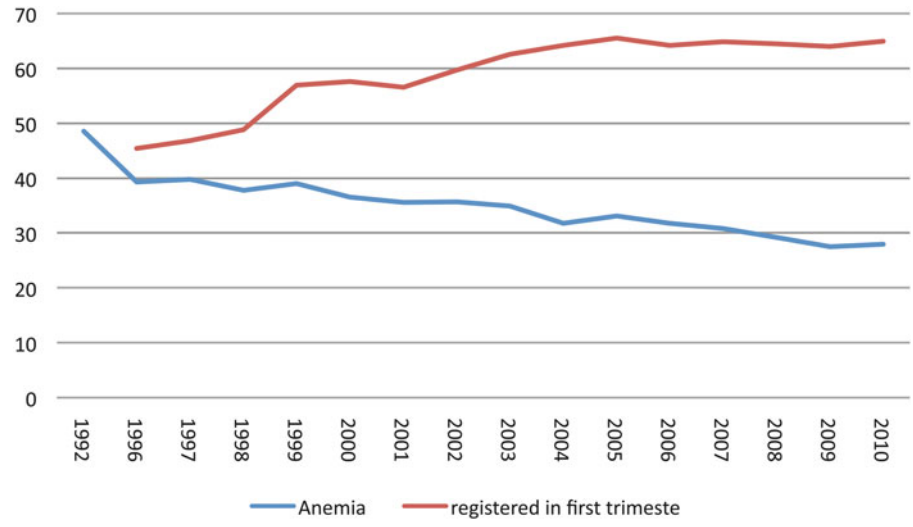

Fig. 25.5 Trend of anemia among pregnant women at first booking, and the percentage screened at the first trimester (unpublished, Department of Statistics and Information, MoH, Oman 2011)

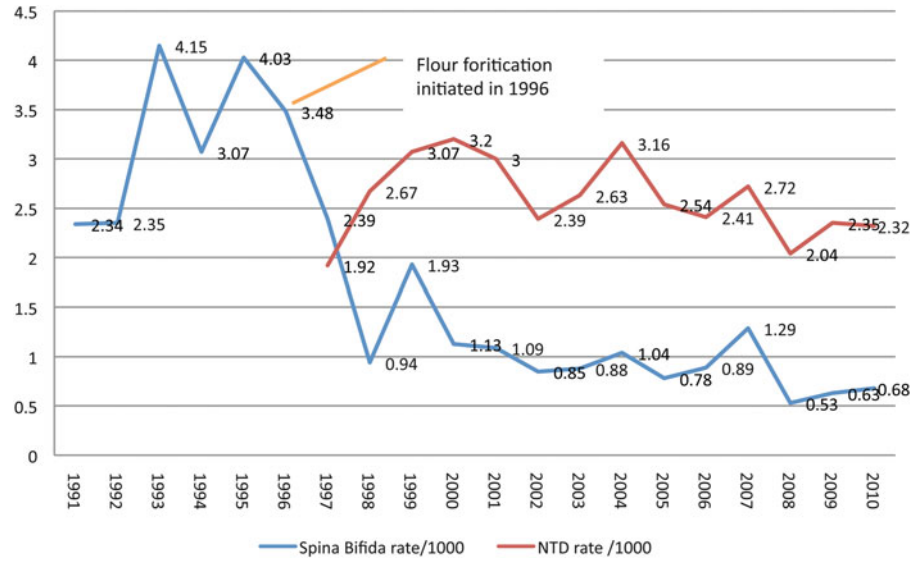

Fig. 25.6 Neural tube defects and spina bifida in Oman 1991–2010 (unpublished, Department of Statistics and Information, MoH, Oman 2011)

Conclusions

Political and Contextual Factors

Oman had been blessed with unique circumstances due to the fact that the Mills industry is contained within two large factories that are well equipped to cope technologically and politically with the introduction of flour fortification. The status Oman Flour Mills acquired among the millers society is a

driving factor to sustain the program (personal communication, Oman Flour Mills, Oman 2011). The low cost of fortification for the millers, estimated at less than US$1/t adds a convenience factor, especially with the large production capacity. However, this may not hold true in all countries where there are multiple mills and sources of wheat and flour.

Quality control and supervision was an achievable component of the program which facilitated issuing the Ministerial decree and was not challenged with hurdles such as limited manpower for supervision and control, and lack of financial resources.

Iron and flour supply from fortification are very different in bioavailability and requirements. Folate had been estimated to have a bioavailability of 60–80 % of the requirements consistently among age groups and it can be added safely to flour at levels that could provide almost 90 % of EAR. Iron on the other hand have low bioavailability, requirements vary greatly between different population groups and its consumption is affected by diet composition, nutritional and health status of the subject, and the form of iron introduced in the flour. Moreover addition of high amounts of Iron could alter the physical properties of bread and baked products making these less palatable.

Another factor of concern is that iron bioavailability is very low in high extraction rate (high fiber) flour and therefore its fortification may not be effective which introduces an additional issue which is striking a balance between fiber and iron recommendations of the diet. In Oman, almost 50 % of the flour produced in 1996 was whole wheat, which is reduced to less than 10 % in 2010. This had been evident in the National Nutrition Survey 2004 which showed that 1–2 % of the grain consumed was whole grain, and various population groups consumed about 40–50 % of the required whole grains [32].

Comorbidities and Genetic Factors

The health and nutritional status of a population are important factors that could promote or confound the effectiveness of flour fortification. The years from 1996 to 2010 in Oman have seen improvement of primary health care services, substantial health education activities, and improvements in wealth and education of the population. On the other hand it was observed that 9.5 % of the children suffered genetic haemoglobinopathies. One cannot ignore that these children could suffer nutritional anemia in addition to the genetically predisposed low hemoglobin levels. On the other hand, it should be noted that their hemoglobin levels will not improve through fortification. Realistically, the minimum prevalence of anemia this population could achieve is above 9 %. Anemia among men in Oman was 12.1 % in 2004 (95 % CI = 7.8–18.2), compared to 14 % in 1993[3] [30].

Outcome

The most pronounced outcome observed was that of folate fortification. Reduction of spina bifida to less than 20 % of its original rate is a significant achievement that has important implications on health cost savings, let alone the value of emotional lifelong strain that affects families and their communities. Number of deliveries in Oman went up from almost 45,000 in 1991 to about 60,000 in 2010. Consistent with Maize fortification (Chap. 7), flour fortification is estimated to avert NTDs of 1,350 births in Oman from spina bifida alone. In the United States, the annual QALYs gained were US$15,842 million from 182 cases gained because of fortification. It was also observed that folate fortification has an important impact on Myocardial infarction, colon cancer, and B12 deficiency masking.

[3] Analysis of data from the National Diabetes Survey 1993.

The QALYs cost of NTDs could be significantly different in Oman, but even with the most conserved approximation it can be concluded that fortification saves millions of dollars annually due to NTDs reduction alone. Colon cancer and Myocardial infarction had more QALY gains than NTDs, which leads to the conviction that fortification may have contributed significantly to national economy.

On the other hand, the impact of iron fortification is inconsistent among various population groups, despite findings of clinical trials (Chap. 7), which illustrates the importance of the context. Trials that are carried under controlled conditions may overestimate the true impact at a population level. In Oman, children had increased rates of anemia over the last few years, and this was more pronounced among the age of 3–5 years who consumed fortified flour. But the rates among women and adolescents are declining. In 2004 anemia among school children was 39 % and 31.8 % among women of childbearing age, both went down to 27.9 % in 2010. Yet these rates rank Oman among countries of severe public health problems for preschool children and pregnant women unlike neighboring gulf countries such as Kingdom of Saudi Arabia and United Arab Emirates, whereas it ranks in medium public health category for women of childbearing age [41].

Recommendations

High rates of anemia among preschool children indicate that concerted and evidence based efforts to control the problem are needed, especially in the view of the increasing trend and the overall rates that exceed 40 %, the threshold for a severe public health problem.

In 2010 a ministerial decree was issued to increase iron in flour and provide more options for fortificants. Surveillance of anemia among women, and newly introduced surveillance of anemia among children at the age of 9 and 18 months will show the impact of this amendment (personal communication, Department of Statistics and information, MoH, Oman).

Finally, the impact of fortification is contextual and is dependent on adequate process and coverage, population health, as well as the economic and social settings. Additional interventions should target high risk population groups and considerations of whole diet approach and prevention of chronic diseases through implementation of food-based dietary guidelines should be incorporated into the design, implementation, monitoring, and evaluation of fortification [44, 46, 49].

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